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PSEUDOCYCLOPS LAKSHMI, A NEW SPECIES (PSEUDOCYCLOPIDAE: CALANOIDA: COPEPODA) FROM THE LACCADIVES, INDIA

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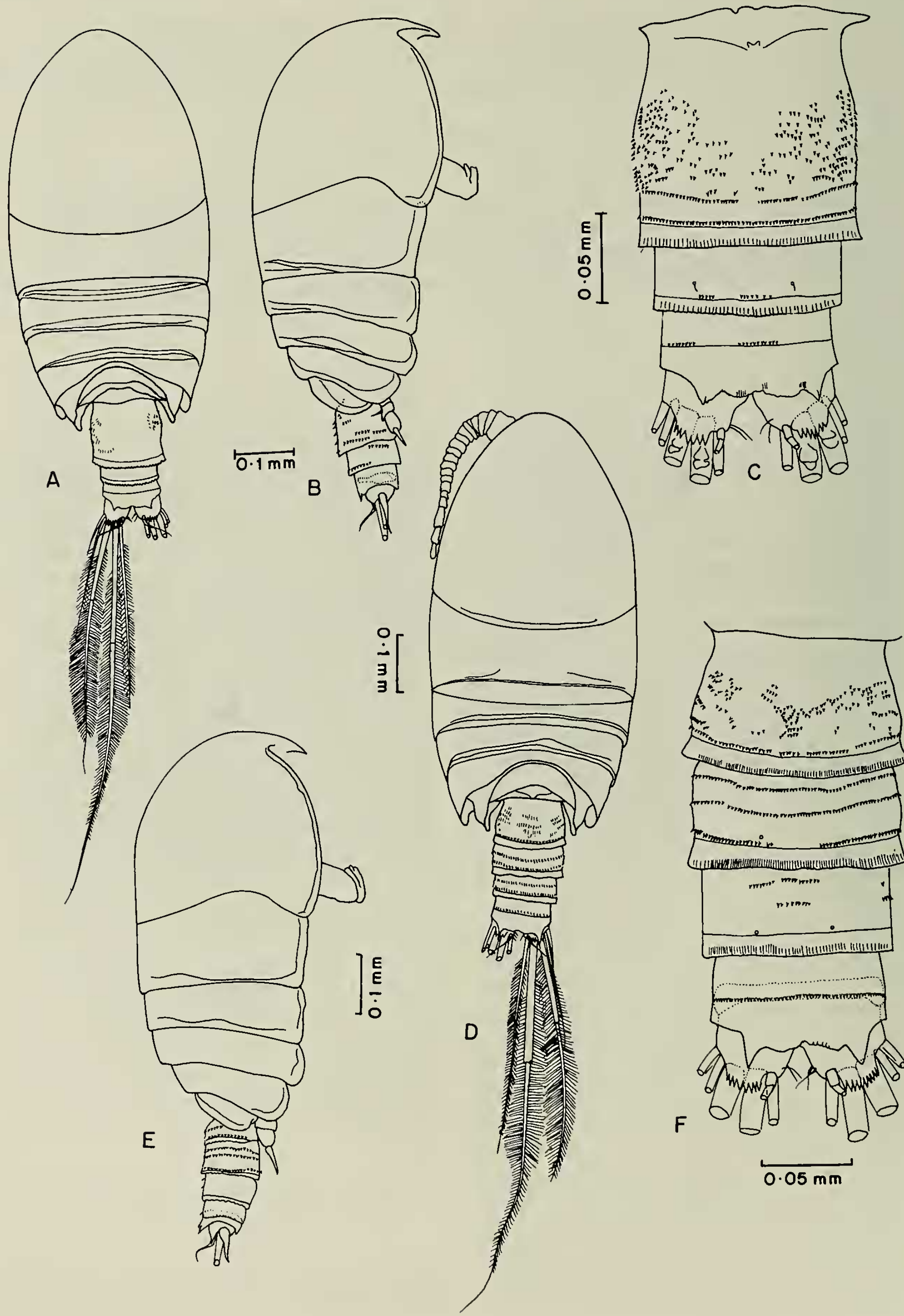
Abstract.—*Pseudocyclops lakshmi*, new species, is described from the Kadmat and Agatti atolls of the Laccadives, India, along with its dimorphic males. Characters separating the new species from the rest of its congeners are discussed. This species is epibenthic and emerges in large numbers into the water column at night.

The hyperbenthic calanoid copepod genus *Pseudocyclops* Giesbrecht, 1893 at present consists of 29 species described from shallow waters of the Atlantic and Indo-Pacific regions (Brady 1872; Brady & Robertson 1873; Giesbrecht 1893; Sars 1903, 1919; Esterly 1911; Gurney 1927; Sewell 1932; Nicholls 1944a, 1944b; Noodt 1958; Bowman & Gonzalez 1961; Vervoort 1964; Tanaka 1966; Wells 1967; Fosshagen 1968; Por 1968; Dawson 1977; Andronov 1986; Othman & Greenwood 1989; Barr & Ohtsuka 1989). Nine species of the genus have hitherto been recorded/described from the Indian Ocean including the Red Sea and Suez Canal, viz. *P. obtusatus* Brady & Robertson, 1873 from the Arabian Sea and Sri Lanka (Thompson & Scott 1903); *P. umbricatus* Giesbrecht, 1893 and *P. latens* Gurney, 1927 from the Suez Canal; *P. latisetosus* Sewell, 1932, and *P. simplex* Sewell, 1932 (type localities of these two species are not given in Sewell 1932); *P. reductus* Nicholls, 1944b, *P. gohari* Noodt, 1958 and *P. steinitzi* Por, 1968 from the Red Sea, and *P. xiphophorus* Wells, 1967 from Mozambique. Their occurrences so far are known only from type localities except *P. obtusatus* which is recorded broadly from the North Atlantic Ocean, the Mediterranean Sea and the Indian Ocean (see Thompson & Scott 1903, Rose 1933, Vervoort 1964, Othman & Greenwood 1989). *Pseudocyclops obtusatus* from the Indian Ocean was reported but not illustrated by Thompson & Scott (1903); there remains the possibility that not all of its records are correct. Similarly, *P. australis* Nicholls, 1944a, originally described from South Australia has been recorded from South Japan (Tanaka 1966) albeit with differences in the structure of exopods of antenna and mandibular palp.

During investigations on zooplankton of the atolls of the Laccadive Sea (Madhupratap et al. 1991a, 1991b), an undescribed species of *Pseudocyclops* was found to be a dominant calanoid copepod in the nighttime net tows in the shallow lagoons of Kadmat and Agatti atolls. Although *Pseudocyclops* species are usually distributed near or on the seabottom, they are often found in the water column due to their vertical migration (e.g., Esterly 1911, Gurney 1927, Vervoort 1964, Fosshagen 1968, Dawson 1977, Othman & Greenwood 1989, Ohtsuka unpublished data). The present paper describes both sexes of the new species of *Pseudocyclops* including the apparently dimorphic males.

Pseudocyclops lakshmi, new species
Figs. 1–7

Material.—Specimens were collected in surface hauls at night using a square net (mesh width 200 μm) from Agatti on 10–



A
B
0·1 mm
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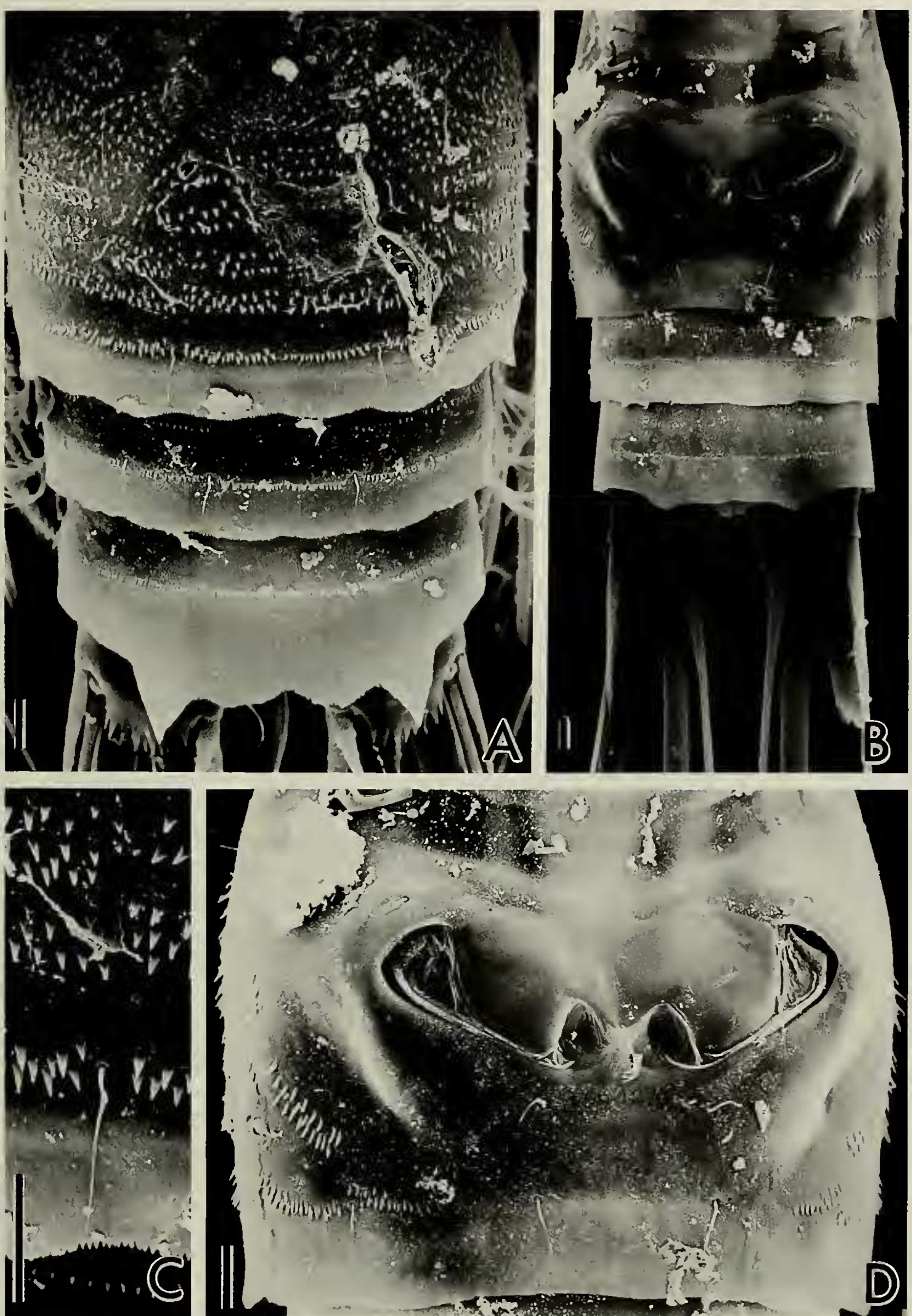

Fig. 2. *Pseudocyclops lakshmi,* Female: SEM photomicrographs. A. Urosome dorsal view; B. Urosome ventral view; C. Distal margin of genital double-somite dorsal view; D. Genital double-somite ventral view. All scale bars = 10 μm.

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Fig. 1. *Pseudocyclops lakshmi,* Female: A. Habitus, dorsal; B. Habitus lateral; C. Urosome. Male: D. Habitus, dorsal; E. Habitus lateral; F. Urosome.

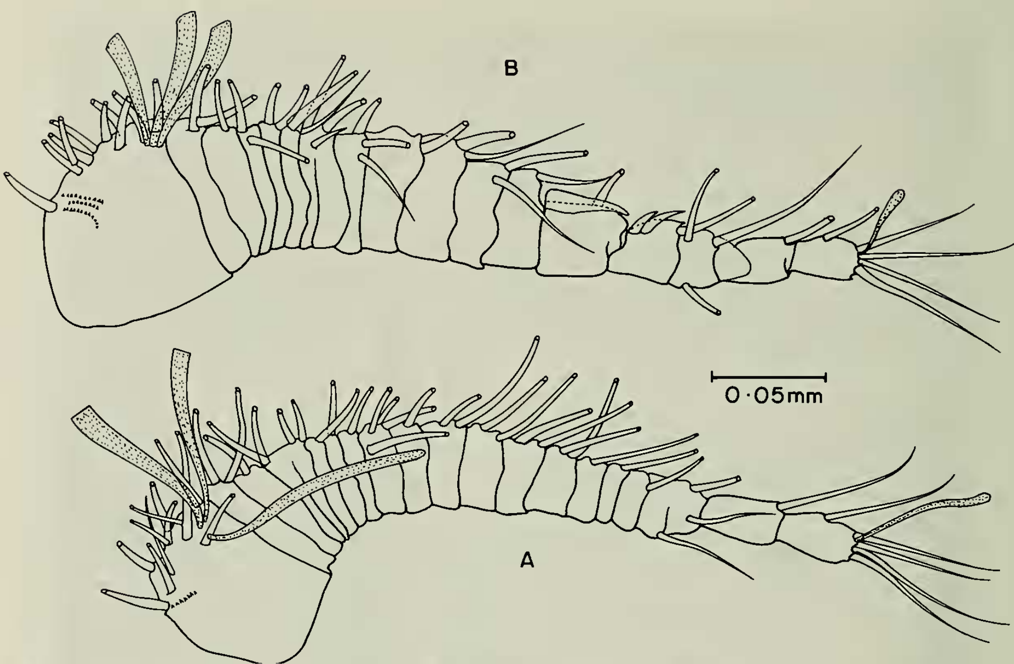

Fig. 3. *Pseudocyclops lakshmi,* Female: A. Antennule. Male: B. Right antennule.

11 Dec 1988 and from Kadmat between 14–16 Dec 1988. The morphological terminology follows Huys & Boxshall (1991). The urosomes of females of the new species were examined with a Scanning Electron Microscope (SEM-JEOL JSM T-20). All types are deposited at the Indian Ocean Biological Centre (IOBC), Cochin.

Types.—Holotype: Female, total length 0.90 mm, IOBC 0405-08-46-1992. Allotype: Male, morph "A"—IOBC 0406-08-46-1992. Paratypes: 10 females & 11 males (6 morph "A" and 5 morph "B"), IOBC 0407-08-46-1992 plus two females and four males dissected and mounted on glass slides IOBC-0408-08-46-1992.

Description.—Female. Body (Fig. 1A, B) 0.86–0.95 mm in total length (average 0.90 mm, n = 13). Prosome oval in dorsal view, cephalosome separate from first pedigerous somite, fourth and fifth pedigerous somites completely separate, posterior corner of fifth pedigerous somite smoothly rounded, reaching to one-third length of genital double-somite. Rostrum pointed, triangular, with a pair of minute sensilla. Urosome (Fig. 1C) 4-segmented, distal margins of first 2 somites lamellar. Genital double-somite largest, as long as following 2 somites combined and covered with numerous minute prominences (Fig. 2A, C). Gonopores and copulatory pores paired, closed off by operculum-like leg 6 (Fig. 2B, D). Second and third urosomal somites with subterminal transverse row of minute spinules; third urosomal somite produced posterodorsally into 2 triangular processes reaching beyond midlength of caudal ramus (Fig. 2A); anal somite small and telescoped into third urosome somite. Caudal ramus with serrate posterior margin dorsomedially and 1 bluntly pointed process ventromedially and with 1 dorsal, 4 terminal and 1 outer subterminal setae.

Antennule (Fig. 3A) 21-segmented, not quite reaching to posterior end of cephalosome; first segment with 3 large aesthetascs and 11 setae; fourth and fifth and eighteenth and nineteenth segments partly fused; terminal segment with one aesthetasc. Anten-

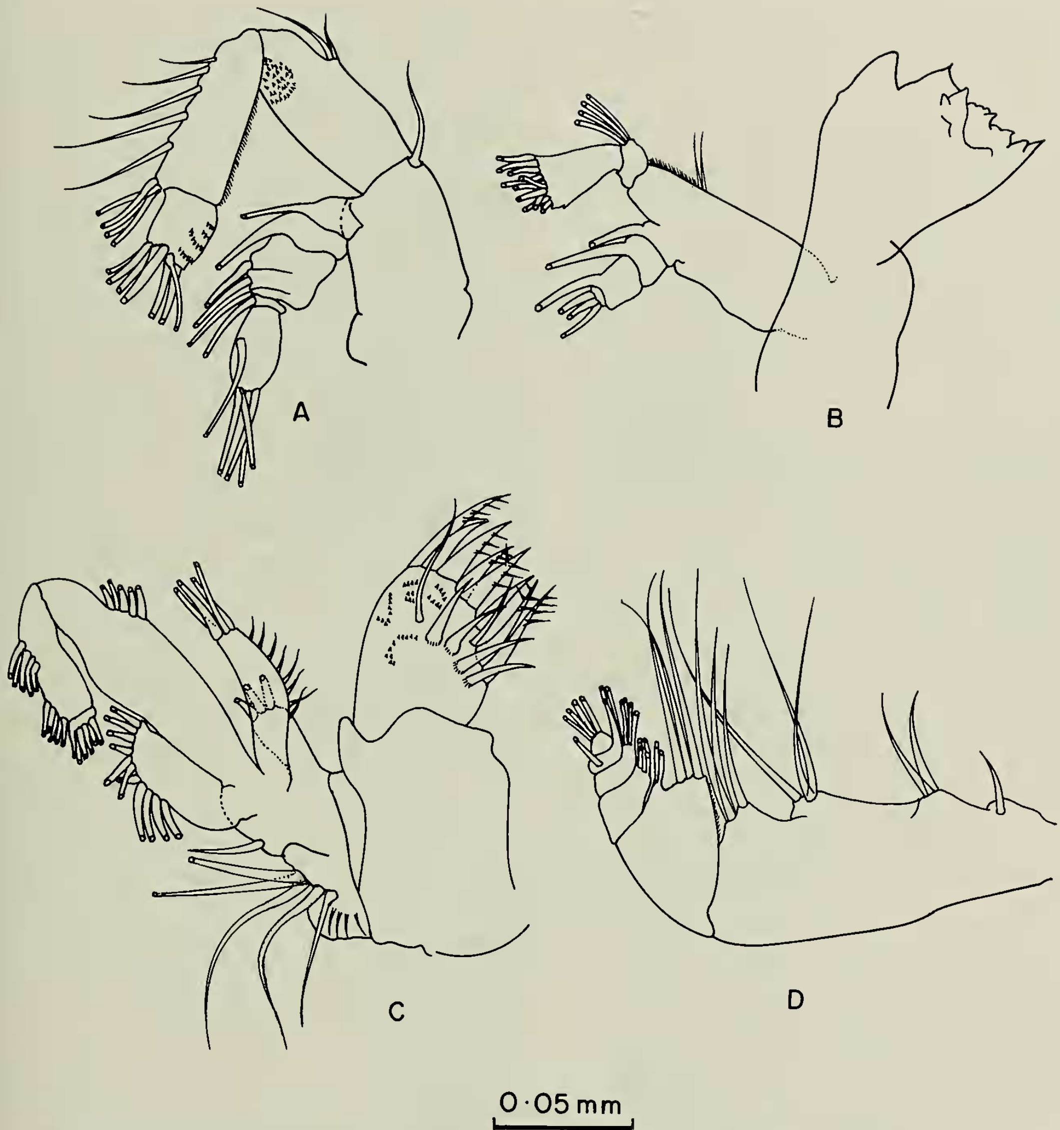

Fig. 4. *Pseudocyclops lakshmi,* Female: A. Antenna; B. Mandible; C. Maxillule; D. Maxilliped.

na (Fig. 4A) basis with seta on inner distal corner; endopod 3-segmented, first segment with 2 setae at midlength of inner margin and subterminal patch of minute spinules, second segment with 5 inner marginal and 4 terminal setae, third segment bearing 7 setae terminally and 4 rows of spinules; exopod 7-segmented, third to fifth segments incompletely fused, first 6 segments each having 1 seta, seventh segment with 1 medial and 4 terminal setae. Mandible (Fig. 4B) gnathobase with 8 blunt teeth; basis with 2 inner setae and patch of minute prominences subterminally; endopod 2-segmented, first segment small, having 4 inner terminal setae, second segment tapering proximally, with 10 terminal setae; exopod 4-segmented, first 3 segments each bearing

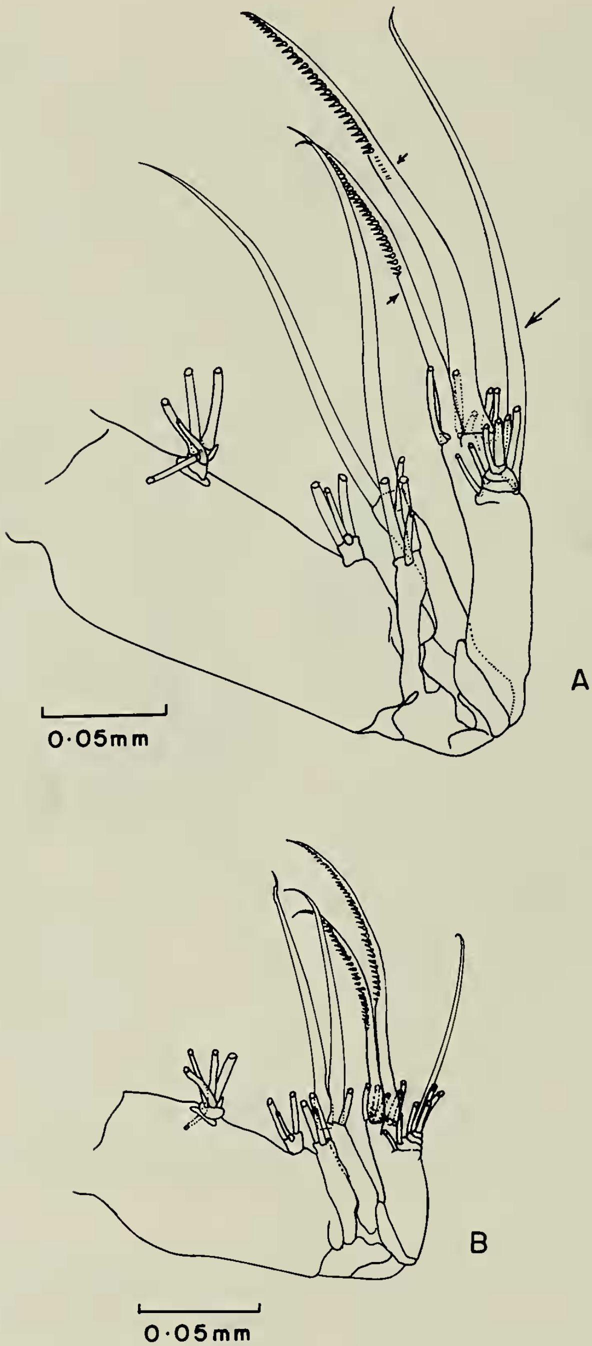

Fig. 5. *Pseudocyclops lakshmi,* Male: A. Morph B maxilla; B. Morph A maxilla.

inner seta, terminal segments carrying 3 setae. Maxillule (Fig. 4C) well developed; praecoxal arthrite with 5 setae on posterior surface and 1 weak and 8 stout spine-like setae along inner margin; coxal and 2 basal endites having 3, 4 and 5 setae respectively; coxal epipodite furnished with 9 setae of unequal lengths; basal exite having short single seta; endopod 2-segmented, first segment bearing 5 middle and 5 terminal setae along inner margin, second segment with 6 terminal setae; exopod 1-segmented, with 11 setae. Praecoxal and coxal endites of maxilla (Fig. 5B, female maxilla similar to morph A of male) having 6, 3, 3 and 3 setae respectively; basis completely fused with first endopod segment to form allobasis, furnished with 7 setae; endopod 3-segmented, first to third segments having 2, 2 and 3 setae respectively. Maxilliped (Fig. 4D) syncoxal endites with 1, 2, 3 and 3 setae respectively; allobasis with 3 medial and 2 terminal setae along inner margin; second to fifth endopod segments each with 4 setae.

Legs 1–4 (Fig. 6A–D) each with 3-segmented rami, all bearing numerous minute spinules on both anterior and posterior surfaces. Exopod segments 1 and 2 with 1 seta, exopod segment 3 with 5 setae except in leg 1 (4 setae), endopod segments 1 and 2 with 1 and 2 setae respectively, endopod segment 3 with 8 setae except in legs 1 (6 setae) and 4 (7 setae). Outer distal corners of second endopod segments of legs 2–4 each produced into bifid process; distal corners of third endopod segments of legs 1–4 acutely produced. Second exopod segment of leg 1 with bulbous process on outer distal corner; terminal spines of third exopod segments of legs 1–4 elongate but not flanged.

Leg 5 (Fig. 6E). Basis with outer subterminal seta on posterior surface; endopod 3-segmented, first segment having a small outer spinule, first and second segment with inner terminal seta, third segment having 1 inner, 1 outer 2 terminal setae; exopod 3-segmented, third segment with 4 flanged spines and 4 inner setae.

Male: Dimorphism was observed only in males. The differences between the two morphs are found in body length and maxilla. In particular, the two morphs differ in the size of maxilla (see Fig. 5A, B). In this paper, males with small and large maxillae are referred to as morphs A and B respectively. Body length of morph A 0.81–0.85 mm (average 0.83 mm, $n = 10$) and that of morph B 0.85–0.95 mm (average 0.90 mm, $n = 10$), prosome of both morphs similar to female (Fig. 1D, E).

Urosome (Fig. 1F) 5-segmented, covered with minute prominences as in the female; first 3 somites with finely striated posterior margin as in female; 2 triangular dorsal processes of fourth somite reaching to distal end of caudal ramus; anal somite telescoped into fourth somite. Caudal ramus with serrate dorsomedial margin and ventromedial blunt process.

Right antennule (Fig. 3B) 18-segmented, geniculate between 14th and 15th segments; first segment with 3 large aesthetascs and 3 rows of minute spinules; seventh and eighth segments fused or separate; 14th segment with sinuous process along whole length of anterior margin; 16th segment produced distally into triangular process reaching midlength of 17th segment; terminal segment with one aesthetasc. Left antennule 21-segmented; fourth and fifth, and eighteenth and nineteenth segments incompletely fused as in female antennule.

Antenna, mandible, maxillule, maxilliped and legs 1–4 of both morphs similar to those of the female.

Maxilla of morph B (Fig. 5A) about twice as long as that of morph A (Fig. 5B); 2 serrate setae on basis (indicated by small arrows) much stouter in morph B than in morph A; seta on second endopod segment (indicated by large arrow) longer and stouter in morph B than in morph A.

Legs 5 of both morphs (Fig. 7A–I) similar to each other except being slightly smaller in morph A. Right leg: coxa and intercoxal sclerite fused; basis separate from coxa, with 1 seta on posterior surface; endopod (Fig. 7A, D, E, F) 1-segmented with small terminal spinules and minute surface spinules, usually without terminal seta; exopod 2-segmented, first segment with stout, flanged terminal spine, second segment with 3 processes, outer long, thick, and medially curved, middle small at base of outer pro-

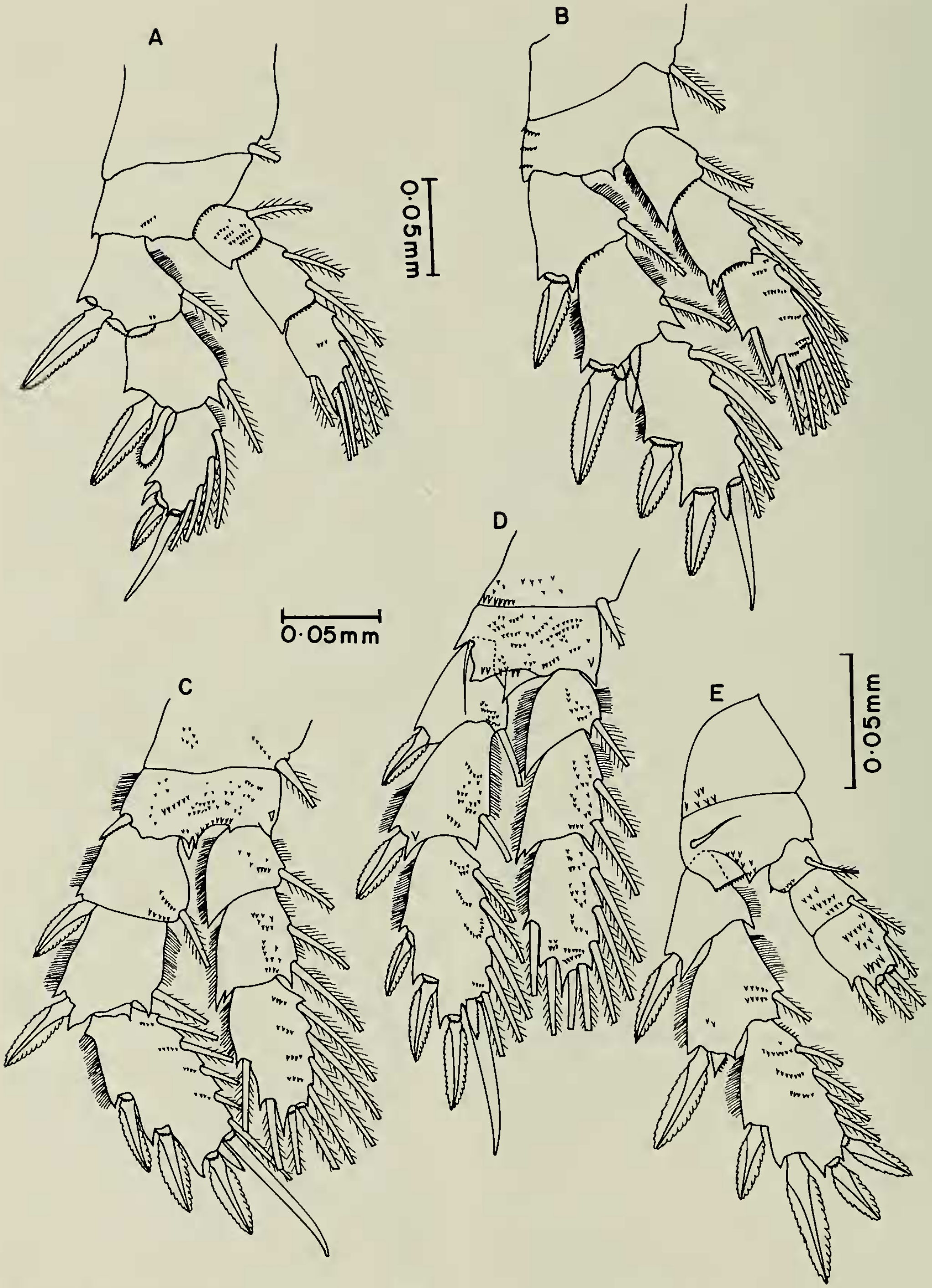

Fig. 6. *Pseudocyclops lakshmi*, Female: A. Leg 1; B. Leg 2; C. Leg 3; D. Leg 4; E. Leg 5.

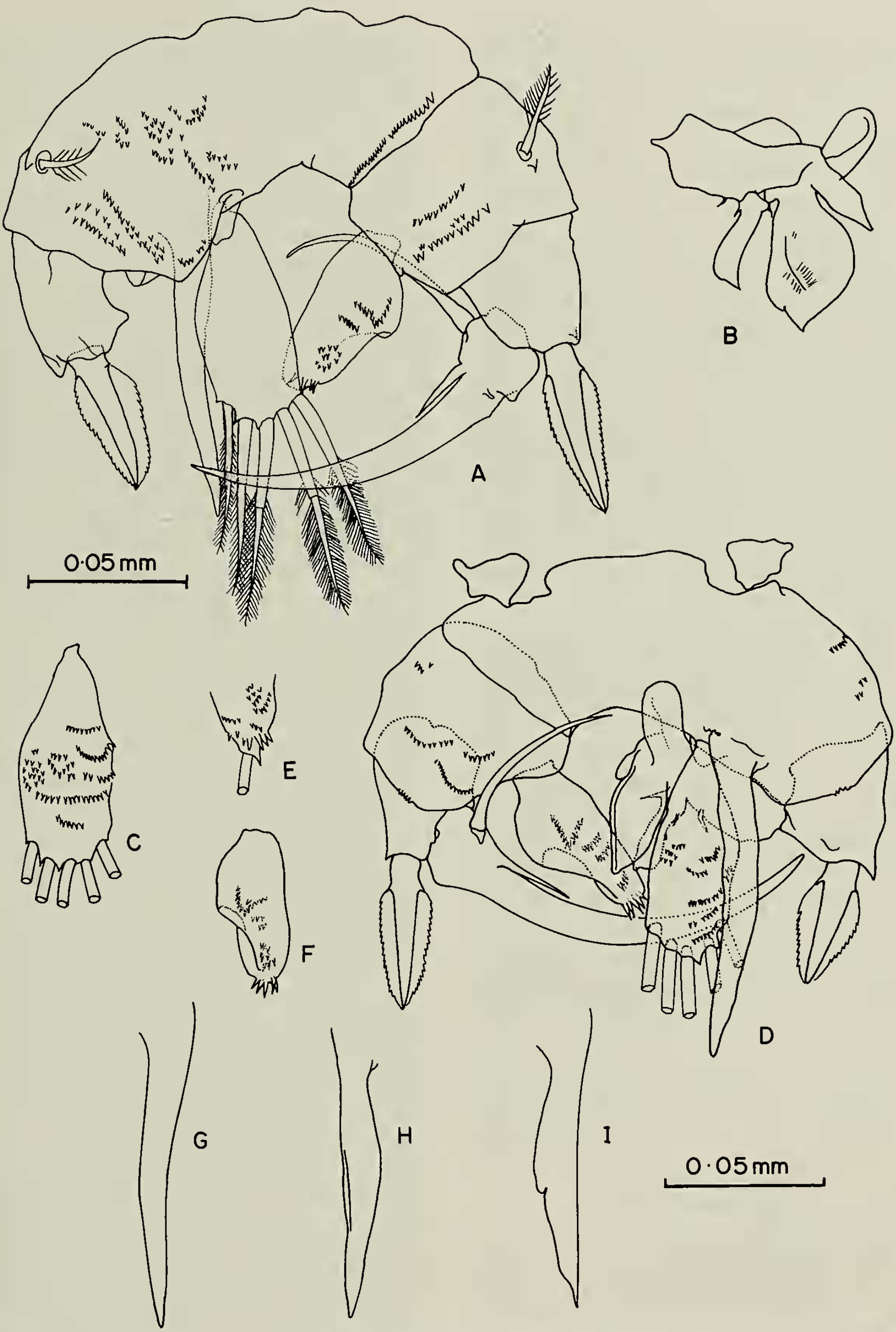

Fig. 7. *Pseudocyclops lakshmi,* Male leg 5: A. Posterior view (left exopod segment 2 omitted); B. Left exopod segment 2; C. Left endopod; D. Anterior view; E–F. Right endopod variability; G–I. Pointed process on basis of left leg showing variability in shape.

cess, inner slender and recurved appearing as chela. Left leg: coxa incompletely fused with basis on both surfaces; basis covered with minute surface prominences, with elongate, pointed process originating from anterior surface (Fig. 7A, D, G, H, I) and 1 seta on posterior surface; endopod (Fig. 7A, C) 1-segmented, with numerous surface prominences and 5 plumose terminal setae; exopod 2-segmented; first segment with outer terminal flanged spine; second segment (Fig. 7B) spoon-shaped, complex and membranous, proximal lobe oblong with 2 hemispherical hyaline processes originating from medial margin and 2 terminal processes, 2 outer processes attached on to outer margin; proximal process rod-shaped with bulbous projection and short seta at base and distal process more or less napiform with subterminal cleft.

Variation.—Segment fusion pattern is variable in right antennule of morph A male—seventh and eighth segments completely or incompletely fused. Right endopod of leg 5 of morph B male has none or 1 terminal seta. The process originating from left basis of leg 5 of morph A male is variable in shape, smoothly tapering distally or having a knob medially (Fig. 7G–I).

Etymology.—This new species is named after goddess "Lakshmi" (Hindu mythology) who symbolizes abundance and wealth. As mentioned earlier, this species is the most abundant calanoid copepod in the two lagoons.

Discussion.—The new species *lakshmi* is one of the most primitive species of the genus *Pseudocyclops*, having 5 separate pedigerous somites, 21-segmented female antennule and 7-segmented antenna exopod; it has an outer basal spine on leg 3, 3-segmented endopod in leg 5 of female and 5 plumose setae on the left endopod of male leg 5. Such primitive characters as 5 separate pedigerous somites, 3-segmented endopod of female leg 5 and 5 setae on left endopod of male leg 5 are found also in *P. australis, P. gohari, P. kulai* Othman & Greenwood, 1989, *P. lerneri* Fosshagen, 1968, *P. mathewsoni* Fosshagen, 1968, *P. reductus, P. rubrocinctus* Bowman & Gonzalez, 1961 and *P. Steinitze* although their antennules and antennae are more advanced.

The present new species, however, has several advanced morphological characters present on the urosome, leg 1 and female leg 5. The urosome is covered with minute prominences, the second exopod segment of leg 1 has an outer bulbous process, and there are 4 setae on the third endopod segment of the female leg 5 (6 setae in *P. kulai, P. lepidotus* Barr & Ohtsuka, 1989, *P. mathewsoni, P. rubrocinctus,* and *P. steinitzi*). The urosome with numerous minute prominences appears to be unique to the new species although *P. lepidotus* has foliaceous scales on the urosome. The bulbous process on the second exopod segment of leg 1 is known in *P. australis* and *P. gohari*; some congeners have a well developed process distal to the outer spine on the second exopod segment of leg 1 different in shape from that of *P. lakshmi. Pseudocyclops lakshmi* seems to be most closely related to *P. australis* from South Australia and Japan and *P. gohari* from the Red Sea in having 3-segmented endopod of the female leg 5 with 4 setae on the terminal segment and a bulbous process on the second exopod segment of leg 1. In particular, the structures of leg 5 of both sexes of *P. lakshmi* resemble those of *P. gohari.* The leg 5 of female *P. reductus* from the Red Sea also shows similarity to that of female *P. lakshmi,* but Nicholl's (1944b) description is too incomplete to compare the two in detail.

Pseudocyclops lakshmi is distinguishable from *P. australis, P. gohari,* and *P. reductus* in metasome, urosome, and legs 1 and 5 in addition to antennule and antenna. Cephalosome and the first pedigerous somite are separate in *P. lakshmi* and *P. australis,* but fused in *P. gohari.* Male *P. gohari* has 8, 8 and 6 well-developed posterodorsal processes on the second, third and fourth urosomal somites respectively; the terminal setae on the caudal ramus are extremely swollen.

The numbers of the antennular segments of the females of *P. lakshmi, P. australis* and *P. gohari* are 21, 18 and 18 respectively. The antenna exopod is 7-segmented in *P. lakshmi* while 4-segmented in *P. australis* (shown as 5-segmented by Tanaka 1966) and *P. gohari.* The mandibular exopod is 2-segmented (Nicholls 1944a) or 5-segmented (Tanaka 1966) in *P. australis* and 3-segmented in *P. gohari* while it is 4-segmented in *P. lakshmi.* The inner distal corner of the basis of leg 1 is prominent in *P. australis* but is not produced in *P. lakshmi* or *P. gohari.* The outer distal corners of the first and second endopod segments of the female leg 5 are strongly produced in *P. australis, P. gohari* and *P. reductus,* but are rather rounded in *P. lakshmi*; there are 4 setae along the inner margin of the third exopod segment of the female leg 5 except for *P. reductus* which has only 1 seta. The right endopod of the male leg 5 has 5 terminal prominences in *P. lakshmi* and 6 to 7 in *P. gohari,* in addition the 2 hemispherical hyaline processes originating along the second exopod medial margin of the left leg 5 in *P. lakshmi* are absent in *P. gohari.* The structure of the male leg 5 of *P. australis* is quite different from that of *P. lakshmi.*

Do et al. (1984) reviewed dimorphism in copepod males. According to them, dimorphism of copepod males is so far known in Calanoida, Cyclopoida, Harpacticoida and Poecilostomatoida. In Calanoida dimorphism in male is reported in families Pontellidae and Pseudodiaptomidae (Johnson 1964, Fleminger 1967, Shen & Mizuno 1984, Walter 1989) and differences occur in characters such as body size and morphology of antennule and leg 5. Dimorphic asymmetry is found in the calanoid genus *Pleuromamma* mostly in the reproductive system (Ferrari 1984). Males of the calanoid copepod *Euchaeta antarctica* produce two types of spermatophores and the same male may produce both kinds of spermatophores (Ferrari & Dojiri 1987). Variations in size ranges of both females and males without morphological differences have been observed in the poecilostomatoid copepod *Oncaea* spp. (Ferrari 1975). The pelagic harpacticoid *Euterpina acutifrons* has two forms of males, namely large and small forms, which have differences in antennule, antenna, developmental rate, sexual behavior, etc. (Haq 1965, 1972). The two forms have varying metabolic rates at different temperatures (Moreira & Vernberg 1968). Variations in the two forms of males of the poecilostomatoid *Pseudomyicola spinosus* parasitic on the blue mussel *Mytilus edulis galloprovincialis* are discernible in body length and slenderness, antennule, swimming legs and caudal ramus. Do et al. (1984) suggested that these differences are indicators of different swimming activity. Similarly, the parasitic copepod *Pachypygus gibber* has a smaller atypical male which is an active swimmer unlike the typical larger male and the former is more efficient reproductively (Hipeau-Jacquotte 1978).

Although there remains a possibility that the two morphs of male *Pseudocyclops lakshmi* may be two distinct species, the absence of females with large-sized maxilla and the co-occurrence of both morphs of males led us to the conclusion that these morphs belong to the same species. Since species of the family Pseudocylopidae usually have well-developed sexual characters in urosome, antennule and leg 5, the invariable sexual characters in both morphs of male *P. lakshmi* support this. It is possible that the feeding behaviors of these two morphs of male *P. lakshmi* may be different because maxilla plays an important role in feeding.

Acknowledgments

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